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The performance of a non-synchronous a.m. detector designed to remove asymmetric-sideband distortion

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

THE PERFORMANCE OF A NON-SYNCHRONOUS A.M. DETECTOR DESIGNED TO REMOVE ASYMMETRIC-SIDEBAND DISTORTION

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(EL-61)

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Summary

Asymmetry between the upper sideband and lower sideband of an amplitude-modulated signal gives rise to distortion of the signal in receivers employing envelope detectors. The use of a synchronous detector removes the problem of asymmetric-sideband distortion. An alternative, non-synchronous, detector has been developed which could replace the envelope detector and which would give less distortion when required to demodulate an a.m. signal with sideband asymmetry. Tests have been conducted on a model of this detector and these are described in this report.

1. Introduction

For distortionless demodulation, the conventional envelope detector must receive an amplitude-modulated signal with symmetrical sidebands. Any asymmetry of the sidebands will result in the envelope of the signal being distorted, and it will not represent the original modulation faithfully. Sideband asymmetry can arise through mistuning of a receiver (when the shaping of the i.f. passband attenuates one sideband more than the other) or through the fading of one sideband relative to the other caused by multipath propagation. The latter can be particularly troublesome at h.f. when long propagation paths are involved between the sender and receiver.

A solution to this problem offered by the more elaborate communication receivers is synchronous demodulation. In order to perform synchronous demodulation, a reference signal in precise synchronism with the received carrier is required. The provision of such a reference is out of the question for many applications such as domestic receivers and cheap communication receivers on the grounds of the very considerable increase in cost which would result.

A cheaper alternative to the synchronous demodulator is the detector developed by Hacking,[1] in which a signal derived from the phase modulation which accompanies an asymmetric sideband signal is used to correct the envelope distortion. An application for a receiver incorporating this type of detector would be for use as a cheap standby receiver for a rebroadcast link, as an alternative to the more sophisticated synchronous receivers used at present.

2. Objective tests: measurement of harmonic distortion

The tests described in this report were made on a model of the Hacking asymmetric-sideband (a.s.b.) detector which was fitted to a high-grade communication receiver. Fig. 1 is a plot of the receiver passband.

Measurements of the harmonic distortion of a sinusoidally modulated carrier were made using envelope and a.s.b. detectors. In order to check the functioning of the detector, both double-sideband (d.s.b.) and single-sideband (s.s.b.) amplitude modulated signals were used, the latter representing the extreme case of sideband asymmetry.

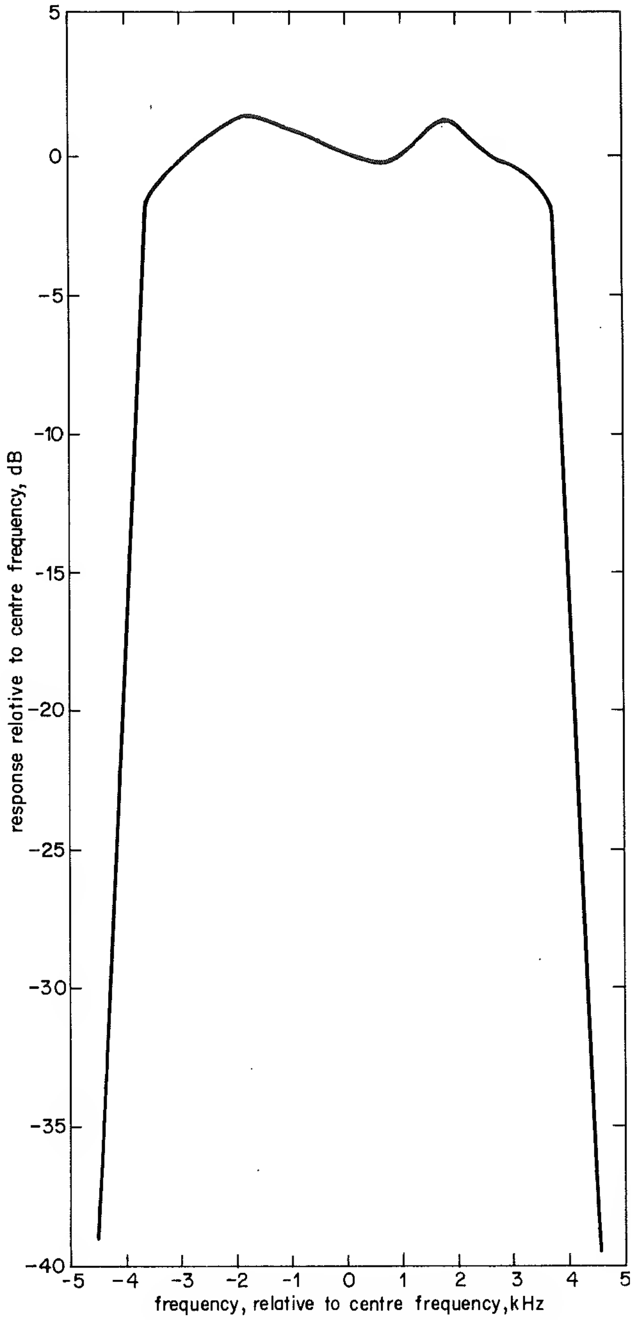

Fig. 1 - Passband response of communication receiver used for tests

Various modulation depths were used for the tests, and the results of the harmonic distortion tests using a modulation depth of 90% are shown in Fig. 2. All results showed the same basic pattern; both types of detector performed very similarly on d.s.b., but as expected the envelope detector gave very severe harmonic distortion on s.s.b. signals (up to 15%). The a.s.b. detector performed quite well on s.s.b., although the optimum setting of the correction signal amplitude did depend to some extent on the modulation depth.

3. Subjective tests

3.1. Comparison of a.s.b. and envelope detectors

Using the experimental arrangement of Fig. 3, subjective tests were conducted to determine whether a panel of listeners preferred the a.s.b. detector or a conventional envelope detector when listening to a programme under conditions of severe fading, typical of that experienced with long-distance h.f. propagation.

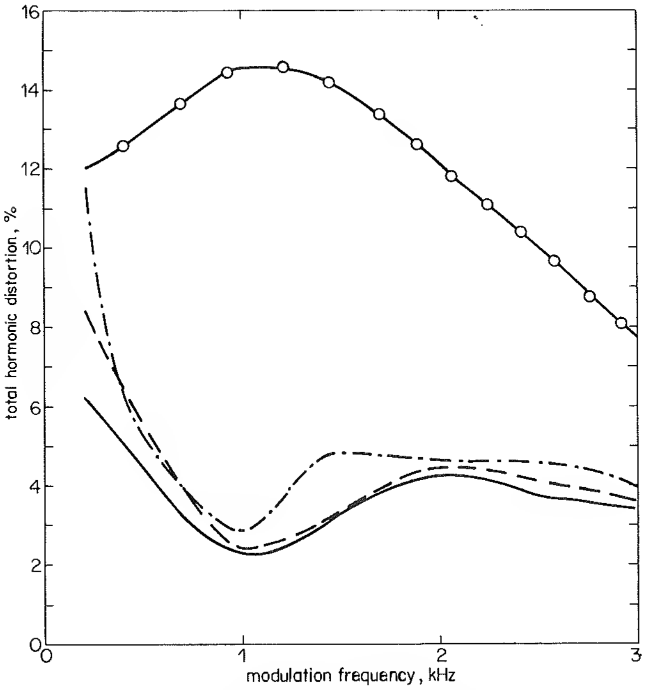

Fig. 2 - Harmonic distortion measured at output of envelope and a.s.b. detectors when supplied with a carrier sinusoidally modulated to a depth of 90%

-o—o- Result for envelope detector with s.s.b. signal
—·—·— Result for a.s.b. detector with s.s.b. signal
— — — — Result for a.s.b. detector with d.s.b. signal
———— Result for envelope detector with d.s.b. signal

It will be seen from the diagram of Fig. 3 that considerable care was taken to simulate the reception of Overseas Service broadcast transmissions accurately. The maximum modulation depth was set to 95% (although peaks of short duration can exceed this value, despite the limiter), and the limiter was adjusted to give 16 dB compression as is used on the Overseas transmissions. After the modulation process the signal passed through a fading simulator[2] and on to the communication receiver fitted with the a.s.b. detector. The fading simulator was adjusted to give a fairly slow rate of fading, with fades every 7 – 10 seconds and deep fades about every 30 seconds. For the first set of tests, the listener was permitted to switch between envelope and a.s.b. detection modes, and express his preference for one or the other on a seven-point scale.* It was not revealed to the subject which detection mode was selected at either position of the switch.

The programme material used for the tests consisted of seven samples; two of speech and five of music, lasting between sixty and eighty seconds. It is usual to select shorter passages than this, but the nature of the fading and the infrequency of the really severe distortion (during deep carrier fades) necessitated the use of relatively long samples of programme material. The variety of musical material available for transmission affords a rather greater choice of test passages than the range of speech programme. It was therefore decided that, in addition to presenting the overall results, separate histograms would be drawn using just the results from the male and female speech tests. If this were not done, there would be a danger that the predominance of music on the test programme material could mask the results for the speech programme.

* These points correspond to those of the 7-grade comparison scale in the CCIR Report 405-1, New Delhi 1970:

+3 A much better than B
+2 A better than B
+1 A slightly better than B
0 A same as B
–1 A slightly worse than B
–2 A worse than B
–3 A much worse than B

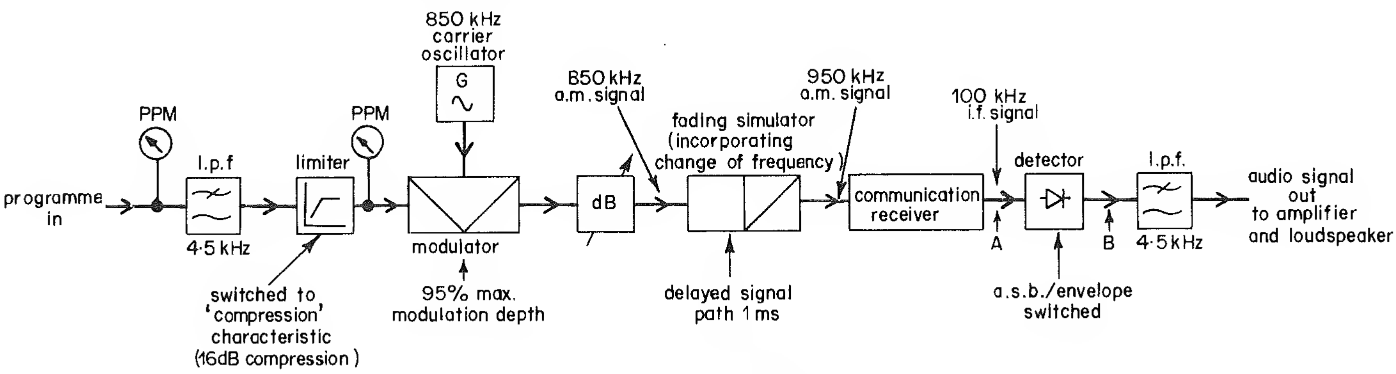

Fig. 3 - Block schematic of equipment for subjective tests

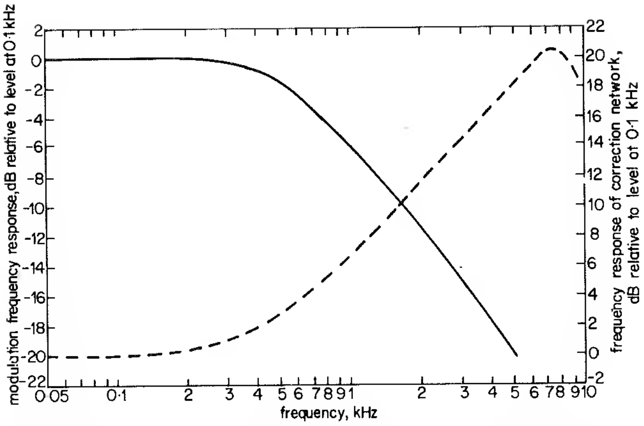

Fig. 4 - Modulation frequency response of a.s.b. detector with 100 kHz carrier enhancement filter and response of equalising network

——— Modulation frequency response of a.s.b. detector with carrier enhancement filter

– – – Frequency response of equalising network used to correct modulation frequency response when carrier enhancement filter is used

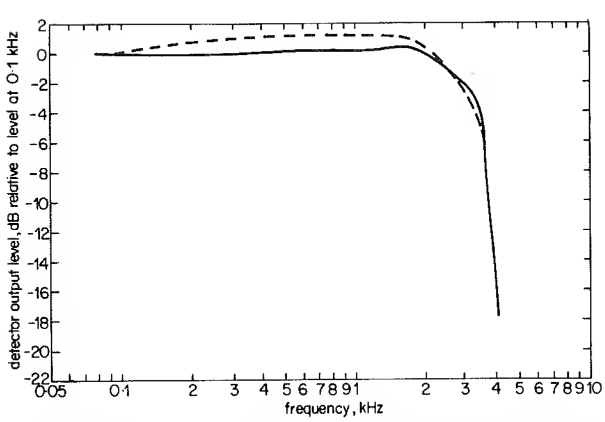

Fig. 5 - Frequency response of a.s.b. detector with and without carrier enhancement modifications, when operating with communication receiver having i.f. bandwidth of ±3·5 kHz

——— Modulation frequency response of a.s.b. detector without carrier enhancement

– – – Frequency response of a.s.b. detector fitted with carrier enhancement filter and equalising network

As modulation depth increases through 100%, the frequency discriminator of the correction signal section of the a.s.b. detector produces a large pulse[1] which impairs the a.f. output. It is thus important when this type of detector is being considered to explore means of reducing the number of occasions on which overmodulation can occur. Provision was therefore made in the tests to include a filter comprising a single tuned circuit at point 'A' before the detector (see Fig. 3) in order to attenuate the sidebands of the signal relative to the carrier.

When the carrier enhancement filter is in circuit, an equalising network is included after the detector at 'B' in order to compensate for the attenuation of the higher modulation frequencies. The modulation frequency response of the a.s.b. detector when fitted with the carrier enhancement filter or the equalising network is shown in Fig. 4; the response when both are used is shown in Fig. 5 together with the basic frequency response obtained with no enhancement or equalisation. The cut-off frequency of 3 kHz was determined by the communication receiver (see Fig. 1).

The results of the first set of subjective tests are shown as histograms in Figs. 6 and 7. These results show the preference of listeners (technical staff) when offered the choice

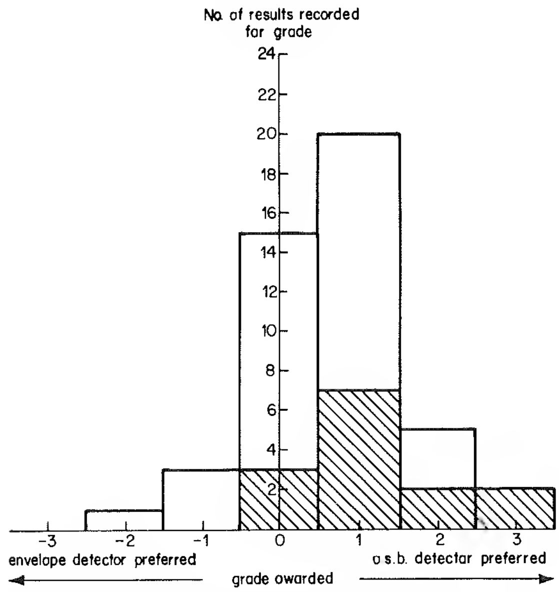

Fig. 6 - Results of subjective test to compare a.s.b. and envelope detectors without carrier enhancement

☐ Overall result ▨ Result for speech programme only

Mean grade is +0·735

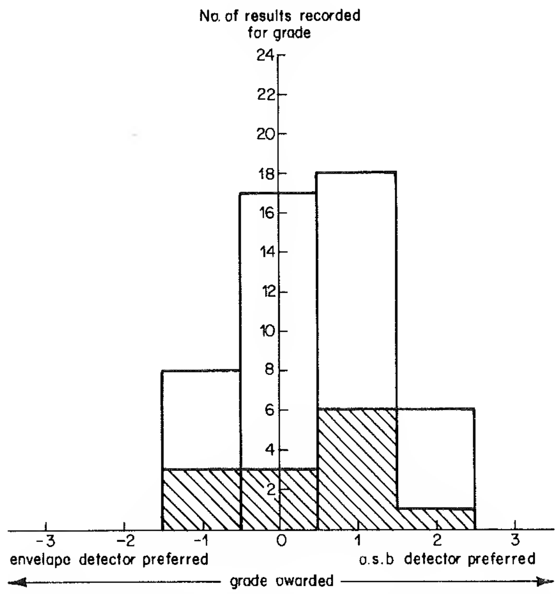

Fig. 7 - Results of subjective test to compare a.s.b. and envelope detectors with carrier enhancement

☐ Overall result ▨ Result for speech programme only

Mean grade is +0·45

of envelope or a.s.b. detectors under test conditions with and without a carrier enhancement filter and its associated equalising network.

3.2. The effect of carrier enhancement

The use of carrier enhancement described in the previous section in order to reduce the effective modulation depth of the signal at the detector raises the question as to whether this technique really produces a worthwhile improvement in the performance of the detector (envelope or a.s.b.). It will be appreciated that the use of the equalising network after a detector can exaggerate the higher-order terms which arise from harmonic distortion, as the network offers a 20 dB boost at 7 kHz relative to its gain at 100 Hz. The use of a 4·5 kHz low-pass filter after the detector helps to remedy this state of affairs, but nothing can be done about distortion terms which arise in the passband of the signal. Thus it is possible for carrier enhancement to degrade the signal.

A second series of subjective tests was therefore conducted, using each detector in turn with the subject listening to a fading signal, as before, and switching the carrier enhancement circuits in and out of the system at will. The results are again presented as histograms, and are shown in Figs. 8 and 9.

4. Discussion of results

The results of all the subjective tests showed a considerable spread of grades, as may be seen from the histograms. A well-defined maximum, corresponding to the subjective grade most frequently selected, is apparent in all cases; this grade is the one most likely to be selected by a listener. Another quantity of interest is the mean grade, obtained by calculating the arithmetic mean of the grades obtained in the test. Both of these figures indicate the impressions formed by listeners of the test conditions being compared, but the mean grade would be influenced considerably by isolated extreme results (for example a particularly offensive sequence of fading which happens to be very infrequent could occur during one of the tests and cause the listener to award a grade based on untypical conditions) and also by the sensitivity of the individual to disturbances of different types in the signal. It is therefore considered better to regard the most frequently selected grade as the more reliable indicator of the comparison between test conditions; any decisions taken on the basis of such a result would in any case be likely to find favour with a majority of listeners. The mean grade and most frequently selected grade are similar where the distribution of results exhibits a high degree of symmetry.

The comparison between a.s.b. and envelope detectors (Figs. 6 and 7) shows that the a.s.b. detector is slightly preferred whether or not carrier enhancement is incorporated in the receiving equipment. The speech programme histograms show that the same results are obtained when assessment is made on the basis of speech intelligibility as when the detectors are compared using a combined programme.

The tests conducted to determine the benefit accruing from the use of carrier enhancement produced the result that performance was neither impaired nor degraded by the carrier enhancement technique when judged on the complete programme of speech and music. When the results for speech alone were considered, it became apparent that the use of carrier enhancement slightly degraded the performance of the a.s.b. detector and slightly improved that of the envelope detector.

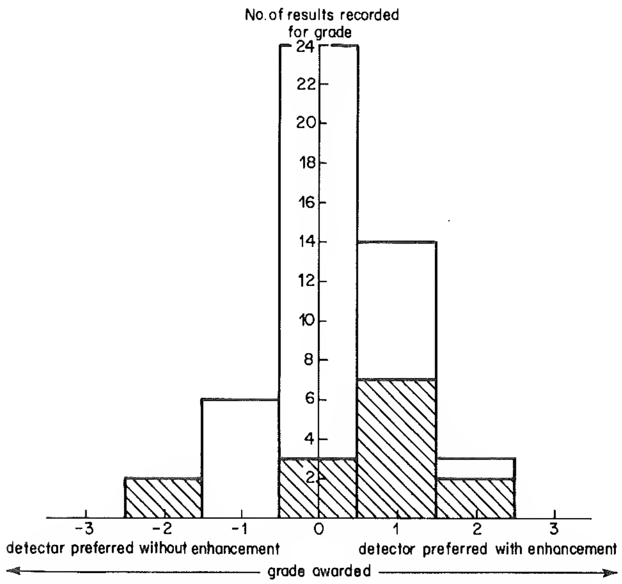

Fig. 8 - Envelope detector: results of subjective test to compare performance with and without carrier enhancement

Overall result   Result for speech programme only

Mean grade is +0·208

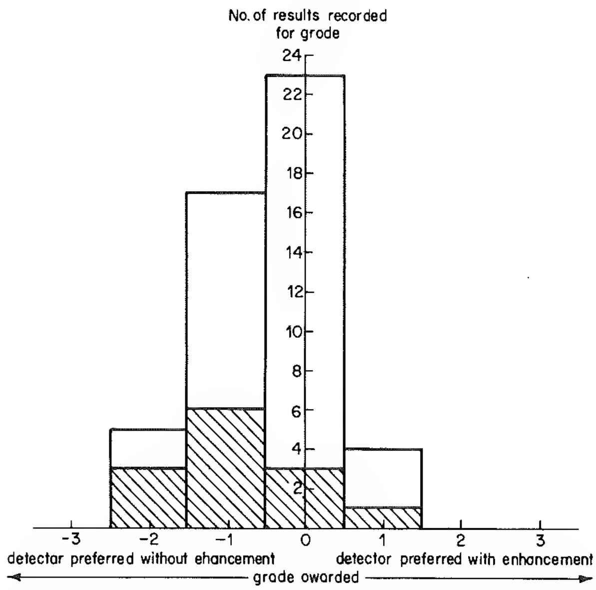

Fig. 9 - a.s.b. detector: results of subjective test to compare performance with and without carrier enhancement

Overall result   Result for speech programme only

Mean grade is –0·47

The objective measurements confirm that the a.s.b. detector performs significantly better than an envelope detector when sideband asymmetry exists. However, subjective tests show that the two devices behave differently at the onset of over-modulation,[1] and a listening test is the only way of judging between the two alternatives taking all aspects of performance into consideration.

5. Conclusions

It is clear from the histograms of Figs. 6 to 9 that there is a small but definite improvement when changing to the a.s.b. detector from an envelope detector. The a.s.b. detector was rated 'slightly better' in the first series of subjective tests, and this grade was awarded most frequently in all four tests (mixed programme and speech with and without carrier enhancement). Thus the conclusion drawn is that this type of circuit offers a small improvement in performance over the conventional envelope detector.

The tests to compare the performance of a receiving system with and without the carrier enhancement filter and equalisation revealed that the majority of listeners could find no improvement or degradation when carrier enhancement was used and when the programme material was predominantly music. The results obtained by considering the speech programme alone show that most listeners think that a slight benefit results from carrier enhancement when used with an envelope detector, and a slight disadvantage when used with the a.s.b. detector. This seems to indicate that the type of over-modulation distortion which occurs with the a.s.b. detector is more offensive with speech, and is emphasised by the equalisation. It is thus apparent that no overall benefit is obtained by using carrier enhancement.

The choice offered is therefore between the two detector circuits without carrier enhancement. A small improvement in performance is obtained under fading conditions or in cases where the receiver has not been correctly tuned with the a.s.b. detector. The increased complexity of this circuit and the need for careful setting up would probably preclude its use in cheap receivers, whilst the more expensive receivers would employ synchronous detection. The a.s.b. detector does not offer a standard of performance suitable for rebroadcast reception; as it has only a marginal advantage over the envelope detector it is unlikely to compete with the synchronous detector for this application.

6. References

1. A non-synchronous method of demodulating amplitude-modulated signals with asymmetrical sidebands. BBC Research Department Report No. 1970/5.

2. A simulator of ionospheric propagation of amplitude modulated signals. BBC Research Department Report No. 1969/24.

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